



Passive strip CMOS detectors

Marta Baselga, Ingrid Gregor, Surabhi Sharma

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What are passive CMOS sensors

What is CMOS?

- ▶ Short answer, is a Compatible Metal Oxide Semiconductor
- ▶ It is a sensor fabricated in a CMOS foundry
- ▶ Has a resolution of some nm
- ▶ Has the photolithography with a machine called stepper, it repeats the mask to different reticles of the wafer (stitching)

[From wikipedia]

Semiconductor
device
fabrication



MOSFET scaling
(process nodes)

10 μm	– 1971
6 μm	– 1974
3 μm	– 1977
1.5 μm	– 1981
1 μm	– 1984
800 nm	– 1987
600 nm	– 1990
350 nm	– 1993
250 nm	– 1996
180 nm	– 1999
130 nm	– 2001
90 nm	– 2003
65 nm	– 2005
45 nm	– 2007
32 nm	– 2009
22 nm	– 2012
14 nm	– 2014
10 nm	– 2016
7 nm	– 2018
5 nm	– 2020

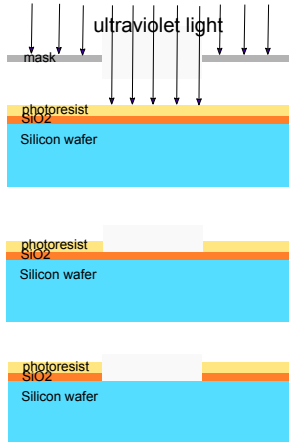
Future

3 nm	~ 2022
2 nm	~ 2023

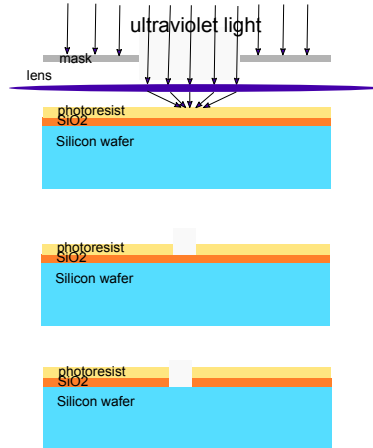
What changes regarding microelectronic foundries?

Photolithography

Microelectronics photolithography



CMOS photolithography



Semiconductor device fabrication

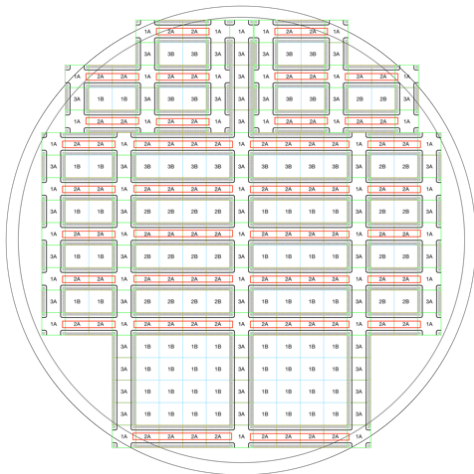


MOSFET scaling (process nodes)

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Passive CMOS

Mask for passive CMOS fabrication



Project

- ▶ Collaboration with Uni Freiburg, Uni Bonn and DESY

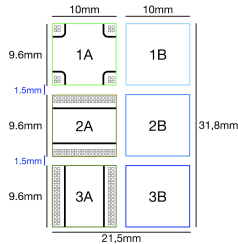


- ▶ Fabricated in LFoundry with 150 nm
- ▶ It has strip and pixel sensors (here in DESY only strips)
- ▶ reticles are around 1 cm^2
- ▶ 1A and 2A are the strip ones (1A is the bottom and top of the strip)
- ▶ strips are 2 cm^2 and 4 cm^2 long

Mask for strips

Strips are 1A, 2A and 3A reticles

Reticule organization



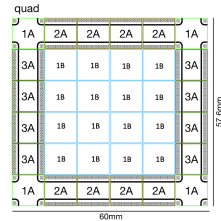
- 1/2/3 A
 - Guard ring
 - “boundary” pixels (100 μm wide area)
- 1B
 - 50 μm $\times$ 50 μm
 - 192 $\times$ 200
 - DC, biased with poly R > 2 M Ω
- 2B
 - 50 μm $\times$ 50 μm
 - 192 $\times$ 200
 - AC capacitor $\sim$ 560 fF + poly R > 2 M Ω
- 3B
 - 25 μm $\times$ 100 μm
 - 384 $\times$ 100
 - DC, biased with poly R > 2 M Ω

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t.wang@physik.uni-bonn.de

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Stitching plan



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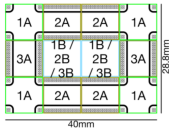
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Mask for strips

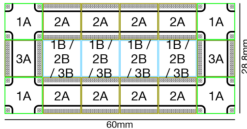
Stitching plan



single



double



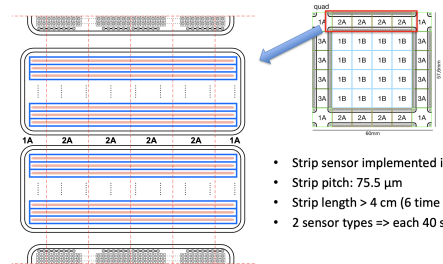
- Type of “boundary pixels” is fixed
 - $50\text{ }\mu\text{m} \times 50\text{ }\mu\text{m}$ DC pixels (type 1B)
- The FE chip may see different pixels at edges

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Strip design



- Strip sensor implemented in 1/2A
- Strip pitch: $75.5\text{ }\mu\text{m}$
- Strip length $> 4\text{ cm}$ (6 time stitching)
- 2 sensor types $\Rightarrow$ each 40 strips

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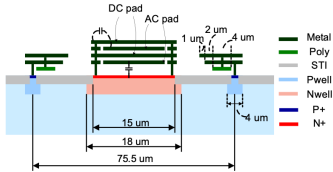
Strip designs. Sensors have two flavours (acctually they are 3)

Regular

Strip 2



- Coupling with parasitic capacitance
 - Parallel metal plate
 - 1st metal and N implant



- ▶ Wafer is 150 μm thick
- ▶ There are 2 strip sensors which 40 strips each
 1. 40 regular strips
 2. 40 low dose strips (20 strips with 30 μm and 20 strips with 55 μm)

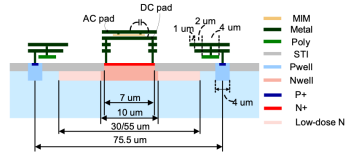
Low dose

Strip 1



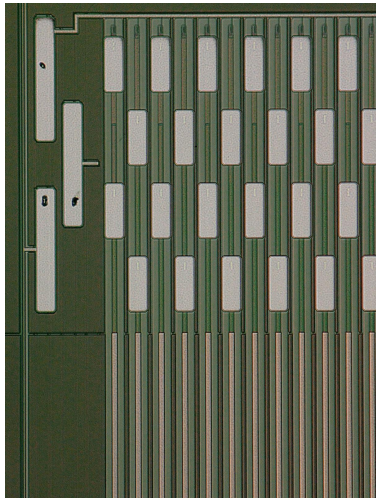
- Coupling with MIM (metal-insulator-metal) capacitor
 - Between MIM layer and 3rd metal
- 2 different Low-dose N implant width: 30 or 55 μm
 - 3.5 MeV implant with 10^{11} doping concentration
 - Each 20 strips

STI: shallow trench isolation (SiO_2)

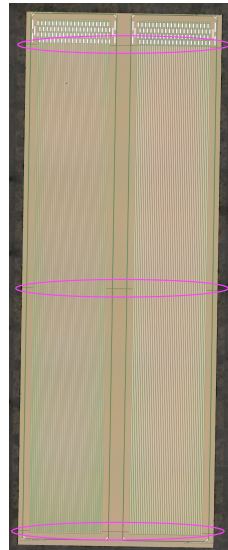
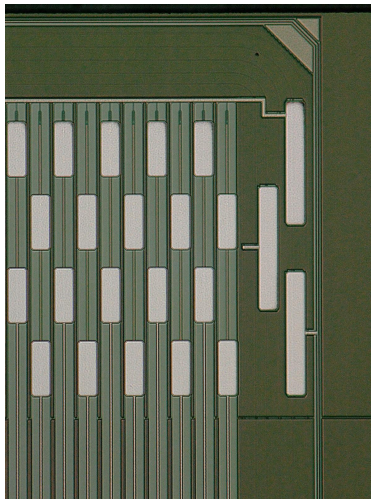


Pictures of the stitching

Regular

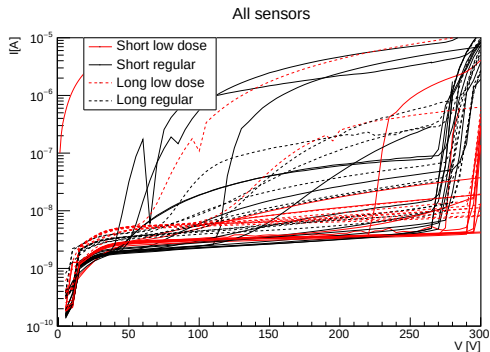


Low dose

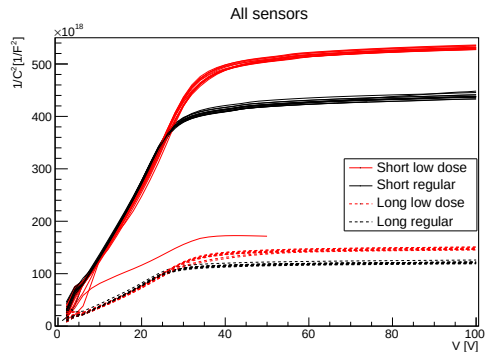


IV and CVs

IV curve



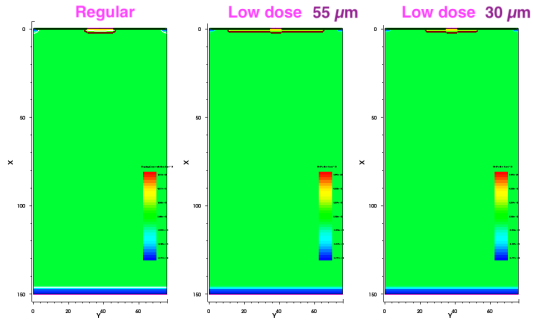
CV curve



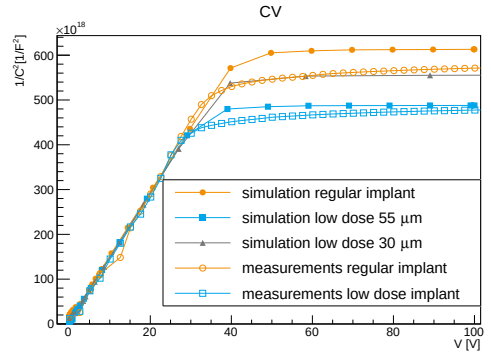
- ▶ The detectors show good electrical performance till breakdown 300 V
- ▶ Due to differences of the strips, they show differences with the CVs
- ▶ They have full depletion at 30 V and 36 V

TCAD simulations

Doping

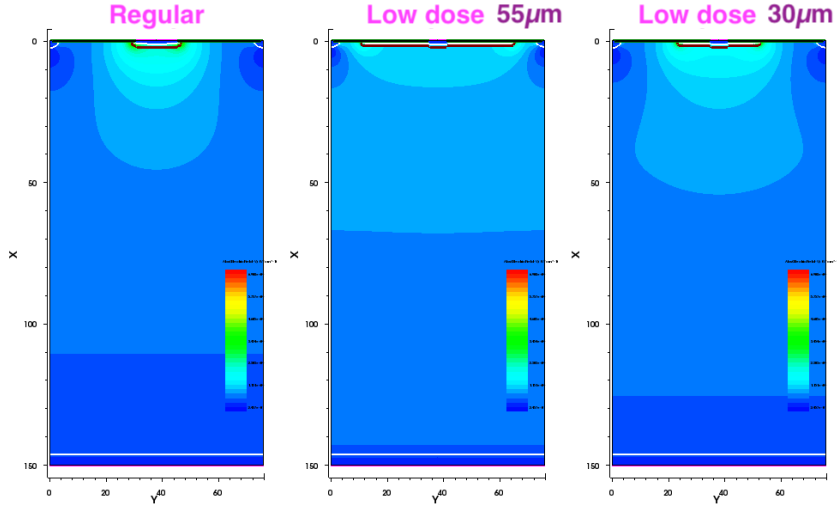


CV comparison



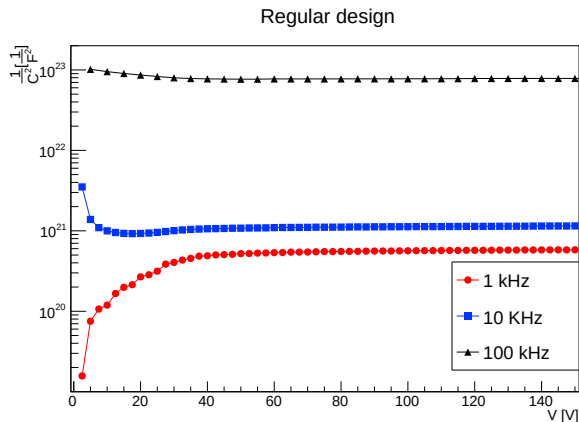
TCAD simulation

Electric field



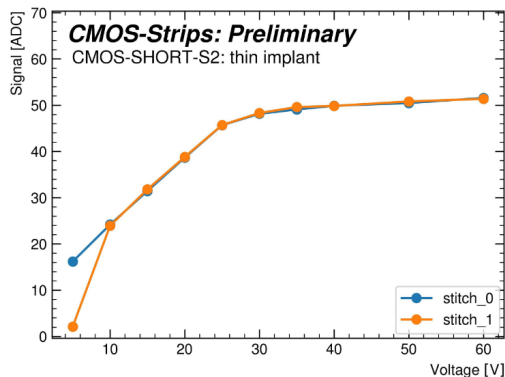
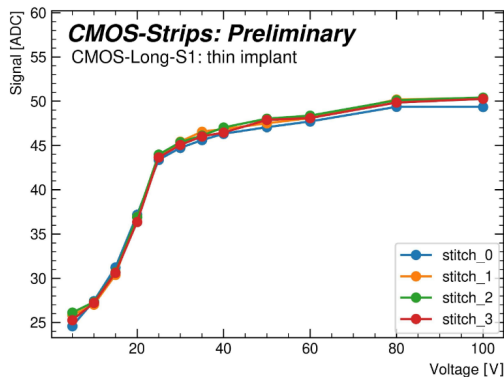
CV measurement with frequency

They have low capacitance for large frequencies



► They have strangely low capacitance for high frequencies

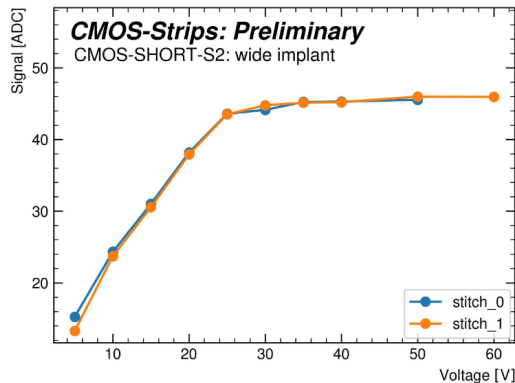
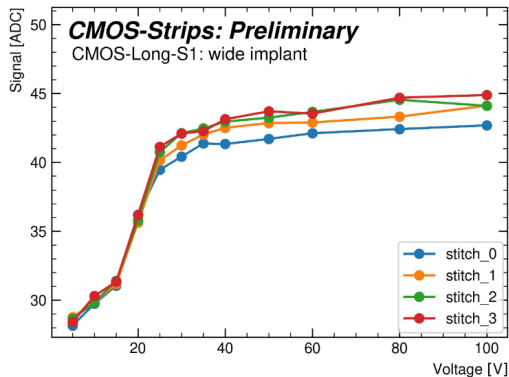
Alibava measurements regular sensor



[Arturo Rodriguez, Trento meeting 2021]

- ▶ Measurements taken with an ALiBaVa setup with Sr^{90} source at 4 different stitching points of the sensors
- ▶ No effect of stitching

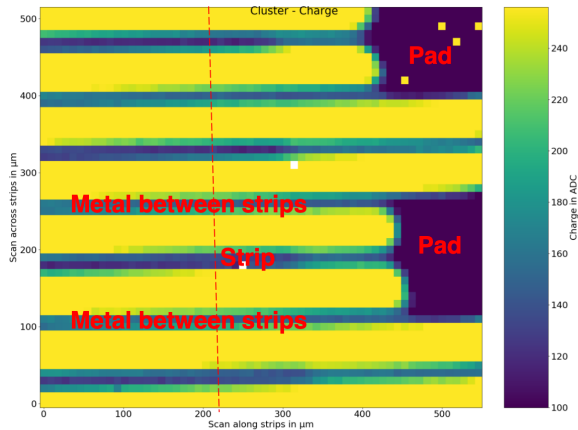
Alibava measurements low dose



[Arturo Rodriguez, Trento meeting 2021]

- Probably some difference due to higher noise of the sensor (noise plot in backup slides)

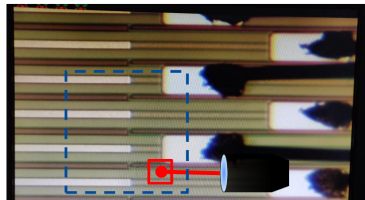
TCT measurements



First measurement to check stitch @ 50 V

UN
FRE

Due to the metallization (blue horizontal lines): results are only hints



20.11.2020

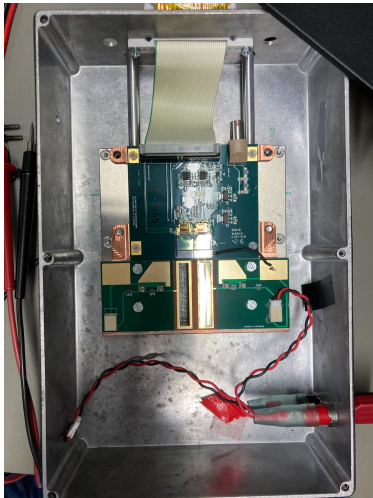
Jan Cedric Hönig - Characterization of passive CMOS strip detectors

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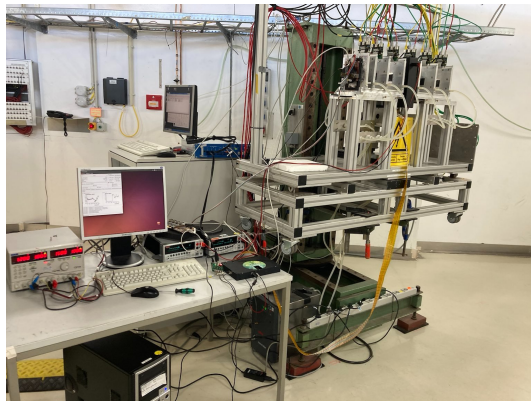
[Cedric Hoenig, RD50 2020]

Testbeam at DESY

Sensor setup with ALiBaVa

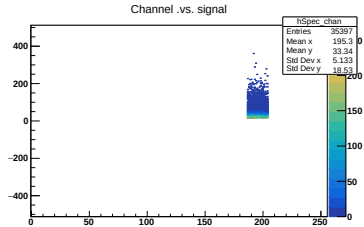
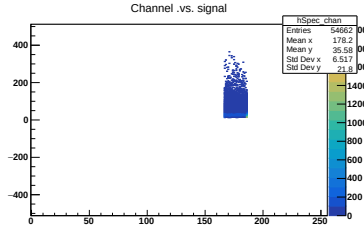


Testbeam at DESY (TB22)

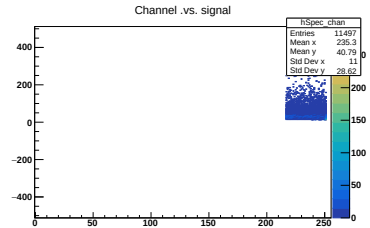


output from alibaba at 100 V

Low dose (separated 20 strips)

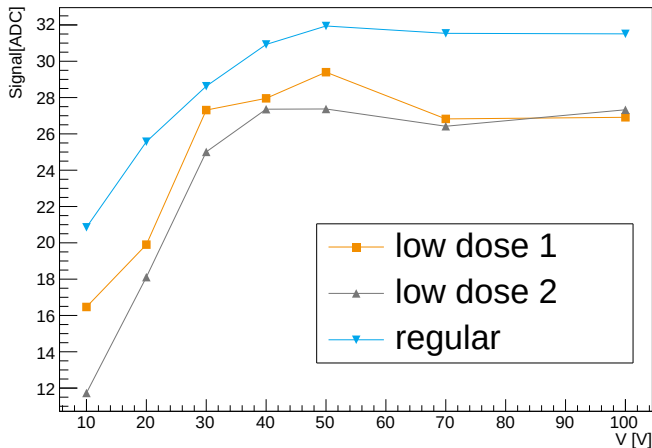


Regular



Alibava from testbeam

Signal for two sensors



Cut at 6

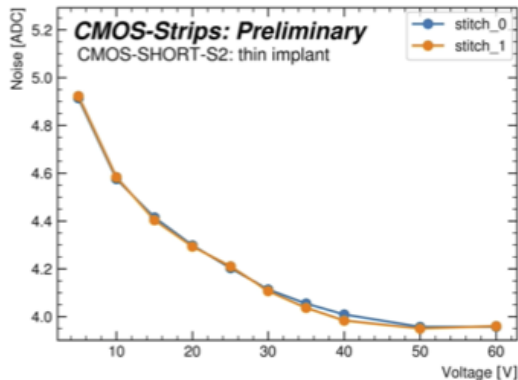
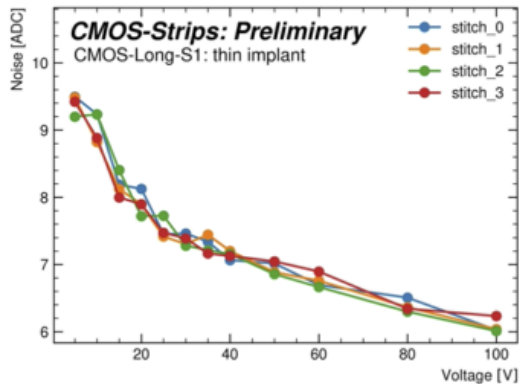
- ▶ Low dose 1 has a strange pattern, maybe not properly analyzed
- ▶ Different cuts show different patterns
- ▶ simulate inter strip capacitance

Future steps

- ▶ Irradiated samples
 - ▶ measure
 - ▶ new testbeams
 - ▶ annealing studies
- ▶ Larger area sensors fabrication
- ▶ Fabricate future non passive strip sensors

backup

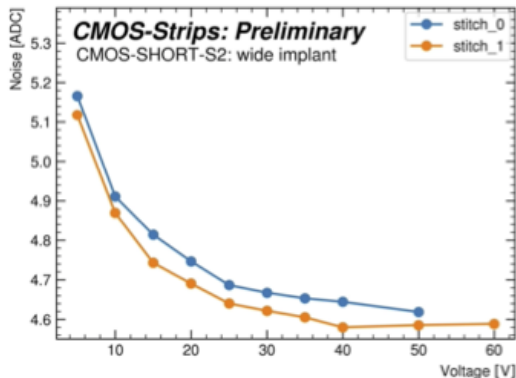
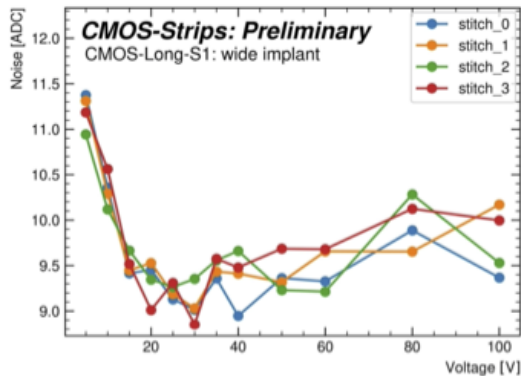
Alibava measurements → Noise



► No effect of stitching

[Arturo Rodriguez, Trento meeting 2021]

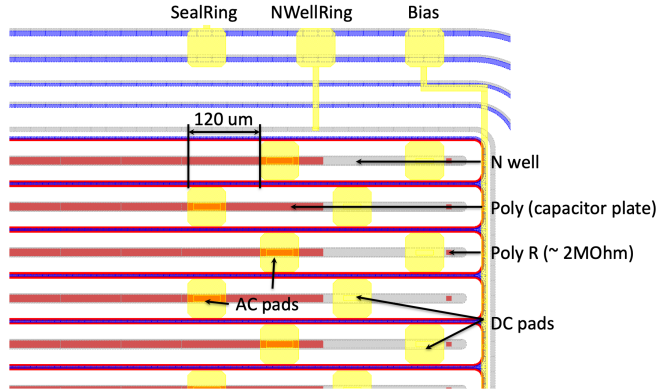
Alibava measurements → Noise



- More difference in the regions, maybe due to higher noise
[Arturo Rodriguez, Trento meeting 2021]

Strips layout

Strip design – pad



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t.wang@physik.uni-bonn.de

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